THE IDAHO PANHANDLE NATIONAL FORESTS WILDFIRE HAZARD-RISK ASSESSMENT

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ABSTRACT

The Idaho Panhandle National Forests (IPNF), in partnership with the University of Idaho, the Fire Sciences Laboratory, and The Sampson Group, developed a Geographic Information System (GIS) based wildfire hazard-risk assessment. The assessment was completed for the North Zone of the IPNF, including sections of federal, state, and private land, to identify geographic locations with the highest wildfire hazards and risks.

The wildfire hazard-risk assessment consists of five models: wildfire hazard-risk (fuel hazard, ignition risk, and precipitation), caribou habitat, timber resources, recreation areas, and human structures. The project area is divided into 201 fire zones. The models identify the distribution of fuel hazards, ignition risks, and important resource values by fire zone. Each model assigns relative hazard scores of very low, low, moderate, high, and very high to the fire zones. It also spatially links output information from the NEXUS Crown Fire Model to forest patches. This is one of the first attempts at spatially linking NEXUS crown fire information to a forest landscape.

Keywords: hazard, risk, wildfire, NEXUS, GIS

INTRODUCTION

The Idaho Panhandle National Forests (IPNF), an administrative consolidation of the Kaniksu, Coeur d' Alene, and St. Joe National Forests, encompasses 2.5 million acres of the Idaho panhandle, which is approximately 50% of all forest lands in the area (Figure 1). This National Forest lies in the east-central part of the Columbia Plateau, just west of the Bitterroot Mountains. Forests include ponderosa pine (*Ponderosa pine*), lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), subalpine fir (*Abies lasiocarpa*), and alpine habitats. Mesic grand fir, western redcedar, western hemlock, and subalpine fir forests dominate the landscape.

Figure 1

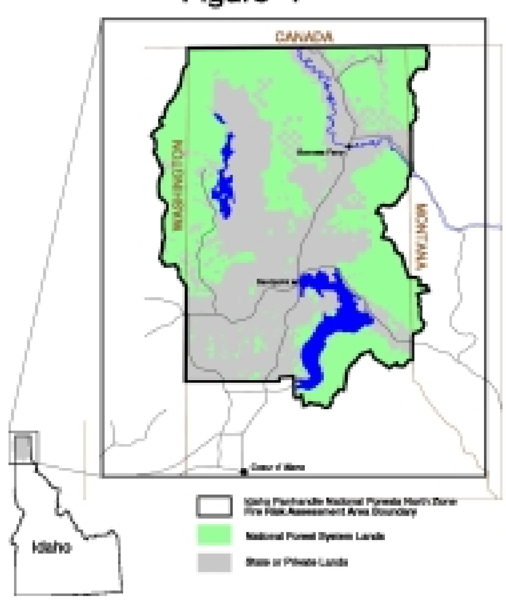


Figure 1. The IPNF (North Zone) Wildfire Hazard-Risk Assessment project area encompasses the Idaho panhandle and parts of Washington and Montana.

Crown fires and mixed severity fire regimes are often associated with these forests with a highly variable fire-free interval ranging from 100-400 years (Habeck 1983). Arno and Davis (1980) found the fire free interval in the lower Priest River drainage to be from 50-150 years. Zack and Morgan (1994) found an even more variable fire-free interval of 18-452 years in the North Fork of the Coeur d' Alene River. Crown fires often occur in drought years under some of the following conditions: low humidity, high temperatures, dry fuels, heavy fuel loads, ladder fuels (vertical fuels that carry fire into the tree crowns), steep slopes, strong winds, unstable atmosphere, and continuous forests.

Most fire ignitions on the IPNF result in little or no damage. However, extreme wildfire events pose unacceptable risks and impacts to suppression forces and resources (Sampson et al 1998). The Sundance Fire (1967), Trapper Peak Fire (1967), Freeman Lake Fire (1931) and the Great Idaho Fire of 1910 are recent examples of stand replacing fires burning under extreme fire conditions in northern Idaho and western Montana (Anderson 1968, Biswell 1989, Jemison 1932, Pyne et al 1996). Historically, these fires burned large areas in short time periods. The Sundance Fire (Pyne et al. 1996) burned 50,000 acres in nine hours, while the 1910 Idaho Fire burned over 3,000,000 acres in 2 days (Biswell 1989, Peterson 1994). These large, extreme fire events can affect caribou habitat, timber resources, human structures, and recreation areas.

Historical logging, the exotic disease white pine blister rust (*Cronartium ribicola*), and fire exclusion have converted the majority of historic western white pine (*Pinus monticola*) and western larch (*Larix occidentalis*) forests to dense, stratified Douglas fir and true fir forests. This forest conversion has increased fuel loads, ladder fuels, and insect epidemics. These forest changes have decreased the probability of mixed severity fire occurrence and increased the probability of severe stand replacing fire occurrence on the IPNF (Harvey et al. 1995, Zack 1996). Fire exclusion may also have influenced present conditions within the long fire-interval forests of northern Idaho (Harvey et al. 1995, Zack 1996).

The IPNF developed a wildfire hazard-risk assessment to evaluate the fuel hazards and the resources at risk to wildfire caused by the last century of forest management. We defined hazard as a fuel condition or state that may result in an undesired wildfire event (Sampson et al 1998). In the IPNF assessment, fuel models, crown bulk density, lower crown heights, and slopes provide a measurement of fuel conditions. Risk is defined as the probability of an event occurring (Sampson et al. 1998). For example, dense housing within a high wildfire hazard area may have a higher probability or risk of burning then homes within a patchy fuel complex.

The wildfire hazard-risk assessment encompasses the North Zone of the IPNF, State lands, and private lands within Idaho, Montana, and Washington (See Figure 1). It was developed to answer the following questions:

- What fuel hazard areas are most at risk to high, intensity, surface fires and large, severe, crown wildfires?
- What areas have the highest probability of ignition?
- What resource values are at risk from high, intensity, surface fires and large, severe, crown wildfires?
- How should managers prioritize the IPNF project area for fuel reduction treatments?

This assessment links a wildfire hazard-risk model to six risk categories - caribou habitat, recreation areas, human structures, and timber resources. It describes where wildfires have the highest probability of occurring and impacting important resources. This information allows managers to focus on hazardous regions that have a high probability of an ignition. It also allows them to perform site specific analyses to determine the appropriate management response within an area.

METHODS

Design Criteria

The hazard-risk assessment was designed according to the following criteria (Sampson et al 1998):

- The model is descriptive and not predictive.
- The assessment is used to prioritize area for further analysis. It should not be used for site-specific watershed, landscape, or project-level work.
- The model does not combine natural resource values at risk (caribou habitat, sensitive plants, watershed and soil integrity, municipal watersheds, flood risk areas, recreation areas, human structures, and timber) in the overall risk rating of each fire zone in order to avoid conflicts between values.
- The model does not address the cumulative effects of small and mixed severity fires.

• The model does not support suppression activities.

Assumptions

The hazard-risk assessment approximates real world conditions and follows these assumptions (Boise National Forest 1996):

• Homogeneous landscapes have a greater chance of being substantially affected by large disturbances.

• Surface fuels, crown bulk density, and lower crown height is uniform within a polygon.

• Weather variables (wind speed, temperature, humidity, and fuel moisture) are constant.

• Fire ignitions include lightning- and human-caused fires.

• Lightning- and human-caused fires will occur in the same patterns as they did from 1974 to 1996 (22 years).

• A receptive fuelbed was and will continue to be present.

GIS Model Development

We used a Geographic Information System (GIS) to analyze the spatial information of the project area. The assessment was formulated through the following process:

1. Five GIS models were created to evaluate fuel hazards, ignition risks, wildfire hazards and risks, and the following important natural and cultural resources:

• Caribou habitat
• Recreation areas
• Human structures
• Timber

2. The fire zone coverage or map was created in ARC/INFO and is the common base for each model. Three elevation zones (< 3,000 ft, 3,000-4,800 ft, > 4,800 ft) divided Landscape Analysis Areas (sub watersheds) from the IPNF Geographic Assessment project to create the fire zones coverage. The output scores for each model were assigned to each fire zone.

3. The models are in 30-m raster format. This format divides the IPNF project area into a grid of 30 m x 30-m square cells that are in rows and columns. Each individual grid cell represents a unique spatial location on the Earth. For each of the models, a relative hazard or risk score of very low, low, moderate, high, or very high was assigned to each grid cell. The scores are based on important features of each model, such as, suitable and optimal habitat, species density, use areas, topography, land use, etc. The final hazard or risk score was assigned to each fire zone based on a mean, maximum, or majority statistic of the grid cells within each fire zone.

Wildfire Hazard-Risk Model

The wildfire hazard-risk model was developed with 3 submodels - ignition risk, fuel hazard, and precipitation (Figures 2, 3 and 4). The submodels were designed separately and combined in ARC/INFO GRID. Three hazard-risk models were created from the ARC/INFO GRID analysis as final products. These models will be tested and reviewed by IPNF fire managers and ecologists over time to determine which provides the best fit for the region.

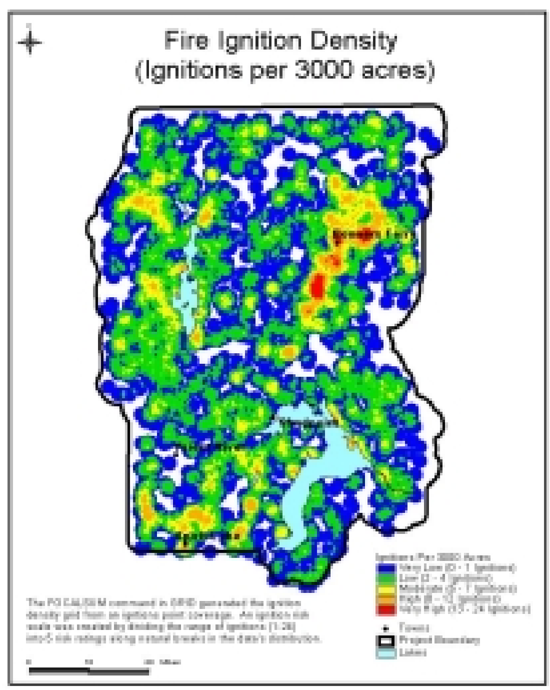


Figure 2. Fire ignitions per 3000 acres were generated with a circular search window in ARC/INFO GRID.

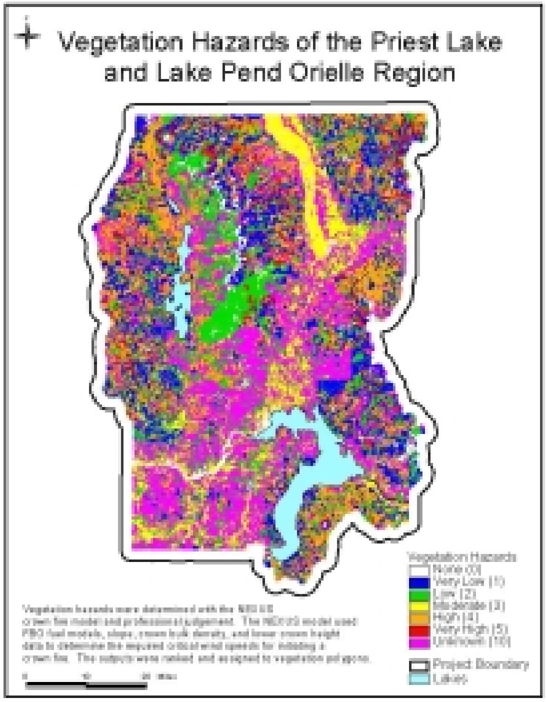


Figure 3. Vegetation hazard scores generated by NEXUS were linked to the Idaho Panhandle National Forests project area.

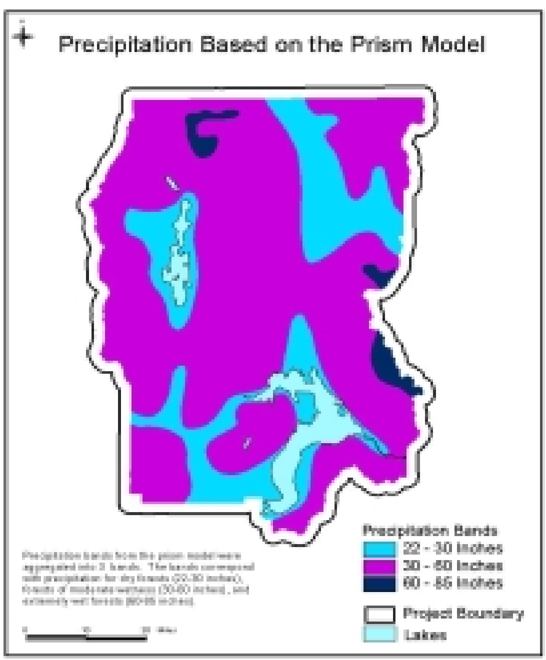


Figure 4. Precipitation bands were generated with the prism model for the Idaho Panhandle National Forests project area.

Ignition Risk Submodel

The ignition risk submodel identifies where lightning and man caused fires have historically occurred in the Idaho Panhandle from 1974 to 1996. The submodel identifies historical wildfire ignitions by 3,000-acre areas. The fire ignition information was compiled from U. S. Forest Service and Idaho Department of Lands records of historical fire ignitions. These records were derived from initial attack reports and were located to the nearest quarter section. False alarm fire ignitions (reports where a fire wasn't present) were not included in the analysis. The ignition records were converted to an ARC/INFO map and then into a 30-m raster grid. Conversion to a raster grid turned the ignition data into a binary data format. A value of one in a grid cell signified the presence of an ignition, while a zero signified no ignition. Ignition density was calculated per 3,000 acres. So, ignitions were totaled for each grid cell with a 3000-acre circular search window (Figure 2). The search window scans out from each cell in the IPNF grid and totals all the cells with an ignition or one value. The sum total is assigned to the cell and then the search window moves on to the next cell. The number of ignitions per 3,000 acres ranged from 0 to 24 ignitions. The range of ignitions was broken into a five-class risk index along natural breaks in data distribution (See Table 1).

Risk Scores	Ignition per 3000 Acres
Very Low (1)	0-1
Low (2)	2-4
Moderate (3)	5-7
High (4)	8-12
Very High (5)	13-24

Table 1. The ignition risk index.

The ignition classes were determined by the professional judgment of the IPNF fire managers and ecologists.

Fuel Hazard Submodel

Fuel hazards were determined with the NEXUS crown fire model (Scott 1999). NEXUS computes the minimum critical wind speed needed to initiate and sustain a crown fire. NEXUS requires 5 data types: fuel model, slope, crown bulk density, height to lower limb, and weather data. The model was run with the following variables:

- Fuel Models: Timber Models (8, 9, and 10)
- Slopes: 0-30%, 30-60%, and 60+%
- Crown Bulk Density: 0.0-0.7, 0.7-1.0, 1.0-2.0, and > 2.0 kg/m3

- Crown Height: 0-1, 1-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20, and > 20 ft
- Wind Speed: 6 mph
- Max/Min Temperature: 99/60° F
- Max/Min Relative Humidity (RH): 100/18%
- Woody Fuel Moisture: 104%
- Live Herb Fuel Moisture: 85%
- 1 Hour Fuel Moisture: 4%
- 10 Hour Fuel Moisture: 7%
- 100 Hour Fuel Moisture: 13%
- 1000 Hour Fuel Moisture: 14%

The critical wind speeds generated by NEXUS were used to develop fuel hazard scores for forest fuel models. In addition, fuel hazard scores were developed with professional judgement for grass and shrub fuel models. The fuel hazard scores were combined into a fuel hazard index (See Table 2).

Rank	Fuel Model
Unknown (0)	Unknown
Very Low (1)	Timber (critical winds > 22 mph)
Low (2)	Shrubs
Moderate (3)	Grass
High (4)	Timber (critical winds 8-22 mph)
Very High (5)	Timber (critical winds < 8 mph)

Table 2. The fuel hazard index.

The final step in modeling fuel hazard was assigning hazard scores to the landscape. A 30-m (raster format) LANDSAT image and ARC/INFO vegetation maps (1:24,000 scale) were used to create fuel model, crown bulk density, and lower crown height grids. A USGS 30-m digital elevation model (DEM) was used to generate a slope grid. The grids were combined to create a grid that represents the input variables of NEXUS. The fuel hazard scores generated by NEXUS for each fuel model, crown bulk density, lower crown height, and slope combination were assigned to the appropriate matching cells within the grid to create the fuel hazard submodel (figure 3).

Precipitation Submodel

The PRISM Climate Mapping Program (www.ocs.orst.edu/prism/prism_new.html) produces and disseminates detailed, high-quality spatial climate data. Digital climate maps are created using PRISM (Parameter-elevation Regressions on Independent Slopes Model). It is an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate estimates of monthly, yearly, and event-based climatic parameters, which include precipitation, temperature, snowfall, degree-days, and dew point. PRISM is designed and constantly updated to map precipitation in topographically complex situations like the IPNF project area.

The North Zone Fire Risk Assessment used the PRISM Annual Precipitation maps (www.ocs.orst.edu/prism/prism_new.html) to adjust ignition risk and fuel hazard submodels (Figure 4). The adjustment is meant to reduce the length of time that forests in higher precipitation zones are in high fire danger situations.

Combining the Submodels to form the Wildfire Hazard-Risk Model

The wildfire hazard-risk models (Hc) are the products of 3 GIS submodels: fuel hazard (Fh), ignition risk (Ir), and precipitation (Pf) (See Figures 2, 3, 4, and 5). The submodels were combined in ARC/INFO GRID. Hazard and risk scores for each submodel were entered into the following wildfire hazard-risk models:

$$\mathbf{Hc = Ir + Fh} \qquad (1)$$

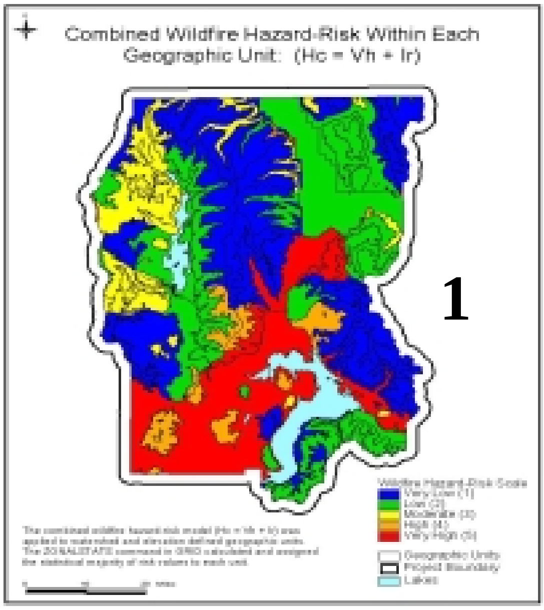
$$\mathbf{Hc = Ir + Fh + Pf} \qquad (2)$$

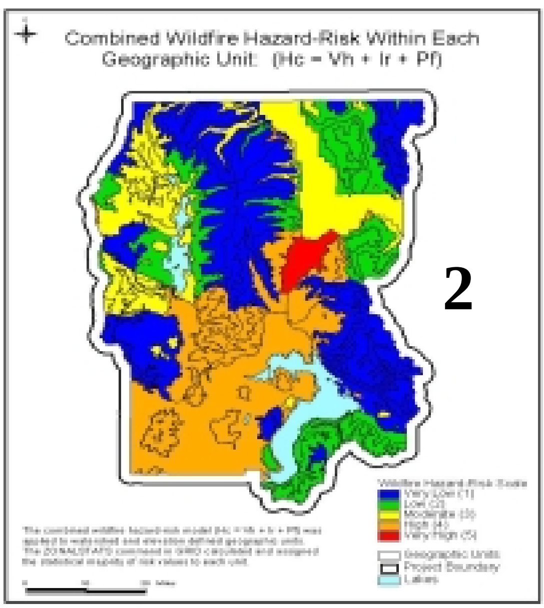
$$\mathbf{Hc = (Ir + Fh) \times (Pf)} \qquad (3)$$

Output values (Hc) from the equations were assigned to each cell in the wildfire hazard-risk models. The wildfire hazard-risk values were divided into 5 classes ranging from very low, low, moderate, high, and very high (See Figure 5). Fire zones were assigned the majority score from all the cells within its perimeter. Based on the professional judgement of IPNF fire managers and ecologists, the majority statistic provided the most reliable wildfire hazard-risk models.

Values at Risk Models

Four resource values were evaluated for risk to wildfire (See Figures 6, 7, 8, and 9). These resources were caribou habitat, timber, human structures, and recre-





ation areas. We used professional judgement based on logical or empirical information and supported by academic theory or experience to create the risk scores for each submodel. Score classes were also determined by logical breakpoints in the data. The primary rule for the overall assignment of scores to the fire zones varied for each model. Mean or majority score assignments were made through professional judgement.

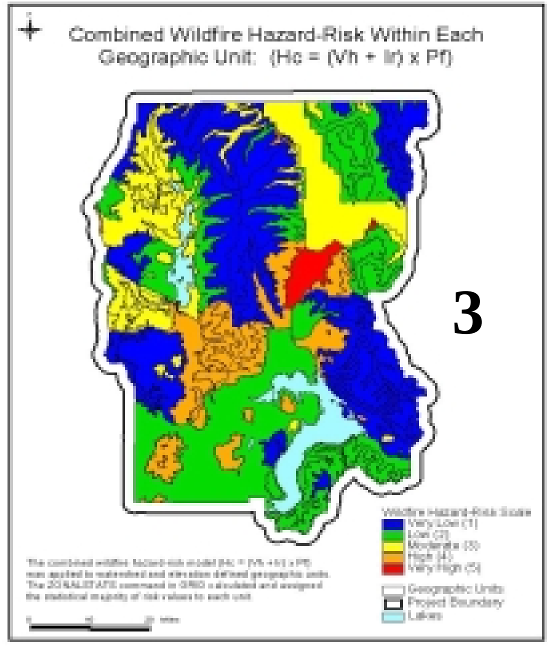


Figure 5. Wildfire Hazard-Risk Models 1, 2, and 3 were generated with the vegetation hazard, ignition risk, and precipitation submodels. Models 2 and 3 have a precipitation factor to account for forests in higher precipitation zones. These forests are at danger to wildfire for shorter periods of time due to their wetness.

RESULTS AND DISCUSSION

Ignition Risks and Fuel Hazards

Ignitions in the project area do not follow a random pattern, but have a distinct pattern. High ignition areas are around travel corridors, populated areas, and areas with high densities of lightning strikes (See Figure 2).

The IPNF project area has only 6% of its area at a moderate to very high ignition risk (See Table 3 and Figure 2).

Ignition Risks	**(%)**
None	65%
Very Low	15%
Low	14%
Moderate	4%
High	1%
Very High	1%
Total	100%

Table 3. Igntion risks by percent (%) of the IPNF landscape.

Fire hazards within the IPNF project area are low to moderate in grass and shrub communities, while forest communities are highly variable and range from very low to very high (figure 3).

Fuel Hazards	Acres (%)
None	79,387 (4 %)
Very Low	384,155 (19 %)
Low	354,210 (17 %)
Moderate	194,020 (9.5 %)
High	397,571 (19.5 %)
Very High	110,595 (5 %)
Unknown	524,896 (26 %)
Total	2,044,834 (100 %)

Table 4. Fuel hazards by acreage and percent of the IPNF landscape.

The IPNF project area has 702,186 acres or 34% of its landscape at a moderate to very high fuel hazard condition (See Table 4 and Figure 3). Approximately a quarter of the IPNF landscape has an unknown fuel hazard, which needs to be determined at a future date. We did not use the unknown fuel hazard areas in developing the wildfire hazard-risk models.

The Wildfire Hazard-Risk Model

The amount of land with a high to very high wildfire risk is similar for all three-wildfire hazard-risk models used in the study (See Figure 5 and Table 5).

Model	M	H	VH	Total
1	40 (11)	25 (5)	14 (20)	79 (36)
2	44 (18)	41 (28)	2 (2)	87 (48)
3	44 (18)	35 (13)	6 (18)	85 (49)

Table 5. Wildfire risks for each hazard-risk model by number of fire zones and percentage of the IPNF landscape (number/percentage). M=moderate; H=high; VH=very high.

Grass communities, human settlements, and transportation routes are prominent in the lowlands of the project area. The ignition density around the settlements and transportation routes is high. The combination of high ignitions within a moderate fuel hazard increases the wildfire risks in these areas. The number of zones and percentage of land area with a moderate to very high wildfire risk increased with the addition of precipitation (See Figure 5 and Table 5). The class divisions in the wildfire hazard index influence the wildfire hazard-risk models. The models will be tested and reviewed over time to determine this influence and which model, if any, has the best fit for the region.

Natural and Cultural Values at Risk

Caribou habitat, human structures, recreation areas, and timber resources were evaluated for potential risk to wildfire.

Resource	M	H	VH	Total
Caribou	14 (09)	01 (01)	9 (13)	24 (23)
Structures	26 (22)	16 (20)	9 (01)	51 (43)
Recreation	21 (14)	10 (09)	3 (01)	34 (24)
Timber	44 (22)	66 (20)	57 (45)	167 (87)

Table 6. Resources values at risk to wildfire by number of fire zones and percentage of the IPNF landscape (number/percentage). M=moderate; H=high; VH=very high.

Human structures and timber resources are most at risk to wildfire in the project area. Human structures at moderate to very high risk composes 43% of the IPNF

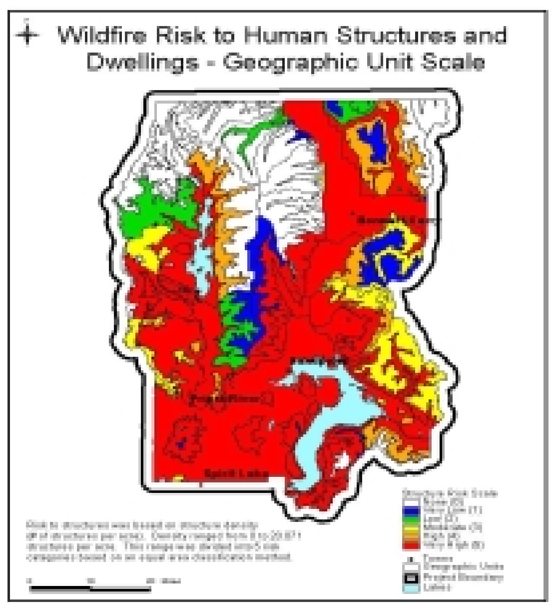


Figure 6. Risk to human structures is highest in the lowlands around the towns of Spirit Lake, Priest River, Sandpoint, and Bonners Ferry.

landscape, while timber resources compose 87% (See Figures 6 and 7 and Table 6). Caribou habitat, human structures, and recreation areas are also at risk to wildfire (See Figures 8 and 9 and Table 6).

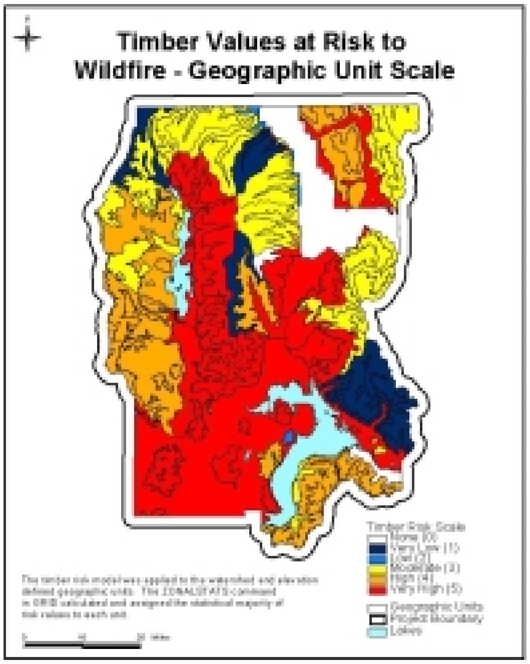


Figure 7. Timber resources are most at risk to wildfire on private and state lands, which form the majority of the very high (5) timber risk value.

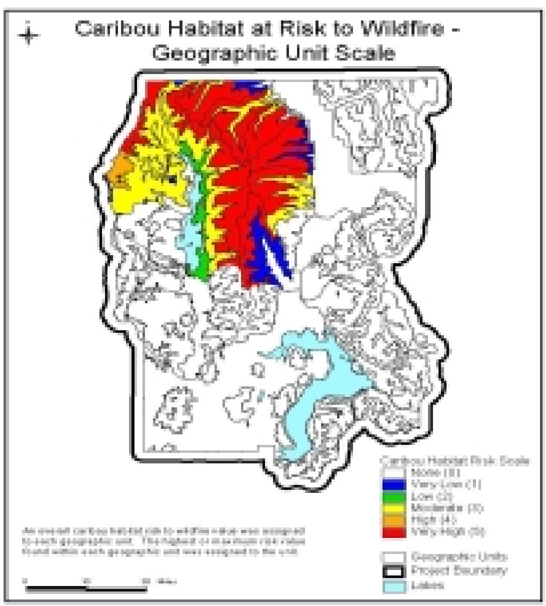


Figure 8. Caribou habitat at risk to wildfire is along the north and east sides of Priest Lake.

Extreme Fire Events

The Idaho Panhandle wildfire hazard-risk model focuses on weather conditions for a normal summer. So, the extreme fire event is not directly modeled in this project. Modeling of these events poses a difficult challenge to fire managers due to their unpredictable fire behavior. The Sundance Fire (circa 1967), Freeman Lake Fire (circa 1931), and the Great Idaho Fire (circa 1910) are examples of fires that can occur in extreme fire weather conditions in northern Idaho (Jemison 1932, Biswell 1989, Pyne et al. 1996). In each case, dry fuels, drought, low humidity, high winds, and high temperatures resulted in fire runs that burned extensive areas. The Sundance Fire advanced 16 miles in 9 hours and consumed 50,000 acres. The average rate of spread was 1 to 6 miles per hour (Pyne et al. 1996). Lengthy spotting distances are another trait of these fires. Spotting of up to 15 miles was reported for the Freeman Lake Fire (Jemison 1932). As Jemison (1932) noted about the Freeman Lake Fire, most forest fuels become available in an extreme event fire. So, land managers and fire officers must question whether we can really model wildfire risk when all fuels become available? That answer is unclear. However, managers can model values at risk to wildfire. Regardless of the type of wildfire burning on the IPNF, managers and fire officers can use the IPNF values at risk models to identify the type and amount of resources potentially threatened by high fuel hazards and wildfire. This knowledge can help managers formulate treatment strategies across the IPNF landscape.

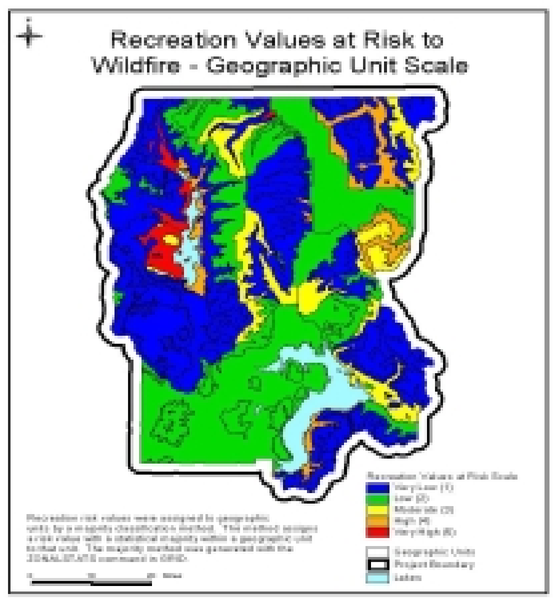


Figure 9. Recreation areas most at risk to wildfire are on the west side of Priest Lake.

CONCLUSIONS

The IPNF assessment is a comparative and descriptive tool. It provides a geographic location of high fuel hazards, ignition risks, and natural and cultural resources at risk. This information will assist fire managers in prioritizing fuel treatment areas on the IPNF. Fire managers can further evaluate prioritized areas at a more site-specific level in order to determine the correct fuel treatments and the appropriate human resources and monetary expenditures for each area.

The limitation of the IPNF assessment is the arbitrary divisions of the hazard and risk scales. These scales were developed with professional judgment. However, professional judgment varies widely between fire managers and scientists. It is important that the IPNF assessment be supported with site-specific studies of the fire zones and further research on the input variables that determine hazard and risk.

ACKNOWLEDGEMENTS

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